Executive Summary: CCT Program Update 2000

Introduction

CCT Program. The Clean Coal Technology Demonstration Program (CCT Program), a model of government and industry cooperation, advances the Department of Energy's (DOE) mission to foster a secure and reliable energy system that is environmentally and economically sustainable. With 26 of the 38 active projects having completed operations, the CCT Program has yielded clean coal technologies (CCTs) that are capable of meeting existing and emerging environmental regulations and competing in a deregulated electric power marketplace.

The CCT Program is providing a portfolio of technologies that will assure that the U.S. recoverable coal reserves of 274 billion tons can continue to supply the nation's energy needs economically and in an environmentally sound manner. At the dawn of the 21st century, many of the clean coal technologies have realized commercial application. Industry now stands ready to respond to the energy and environmental demands of the new century, both domestically and internationally. For existing power plants, there are cost-effective environmental control devices to control sulfur dioxide (SO_2), nitrogen oxides (NO_x), and particulate matter (PM). Also ready are a new generation of technologies that can produce electricity and other commodities, such as steam and synthetic gas, and provide the efficiencies and environmental performance responsive to global climate change. The CCT Program took a pollution prevention approach as well, demonstrating technologies that produce clean coal-based solid and liquid fuels by removing pollutants or their precursors before being burned. Lastly, new technologies were introduced into the major coal-using industries to enhance environmental performance. Thanks in part to the CCT Program, coal—abundant, secure, and economical—can continue in its role as a key component in the U.S. and world energy markets.

Fiscal Year 2000 Major Accomplishments. Early in fiscal year 2000, the Wabash River Coal Gasification Repowering Project successfully completed demonstration operations. The final report was issued and the project was closed out by the end of the year. Beyond the integration of an advanced integrated gasification combined-cycle system with a 1950s vintage pulverized coal-fired plant, the project incorporated other features that resulted in a 40 percent efficient unit. These include: (1) hot/dry particulate removal to enable gas cleanup without heat loss, (2) integration of the gasifier and high-temperature heat recovery steam generator to ensure optimum steam conditions for the steam turbine, (3) use of a carbonyl sulfide hydrolysis process to enable high-percentage sulfur removal, (4) recycle of slag fines for additional carbon recovery, (5) use of 95 percent pure oxygen to lower power requirements for the oxygen plant, and (6) fuel gas moisturization to reduce steam injection requirements for NO_x control.

The Healy Clean Coal Project successfully completed demonstration operations early in fiscal year 2000. The project was the first utility-scale demonstration of the TRW advanced entrained (slagging) combustor. The project eclipsed extremely strict environmental operating permit emission limits, which were required because of the project's proximity to the environmentally sensitive Denali National Park and Preserve, with typical emissions of 30 percent, 56 percent, and 77

Tidd PFBC Demonstration Project (The Ohio Power Company)—1991 Powerplant Award presented by *Power* magazine.

Tampa Electric Integrated Gasification Combined-Cycle Project (Tampa Electric Company)—1997 Powerplant Award presented by *Power* magazine.

percent below permit emission limits for NO_x (0.350 lb/10^6 Btu), SO_2 (0.086 lb/10^6 Btu), and PM (0.02 lb/10^6 Btu), respectively. The project is now in the reporting phase.

Final reports were issued and the following projects closed out:

- Micronized Coal Reburning Demonstration for NO_x Control,
- Milliken Clean Coal Technology Demonstration Project,
- Integrated Dry NO_x/SO_2 Emissions Control System, and
- Blast Furnace Granular-Coal Injection System Demonstration Project.

The cooperative agreement was novated and a new site approved for the Kentucky Pioneer Energy IGCC Demonstration Project. The National Environmental Policy Act (NEPA) process, which includes preparing an Environmental Impact Statement (EIS), was started for the project.

Throughout the year, the CCT Program staff participated in over a dozen domestic and international events involving users and vendors of clean coal technologies, regulators, financiers, environmental groups, and other public and private institutions. Four issues of the *Clean Coal Today* newsletter were published in the same period, along with the fifth annual edition of the *Clean Coal Today Index,* which cross-references all articles published in the newsletter. A 12-page *Project Performance Summary* document was issued for the ENCOAL® Mild Coal Gasification Project. An updated *The Investment Pays Off* document, capturing the latest contributions of the CCT Program to advancing coal technologies, was published. *Clean Coal Technology Topical Reports* were issued during the fiscal year for the Tampa Electric Integrated Gasification Combined-Cycle Project and the Blast Furnace Granular Coal Injection System Demonstration Project. Also, DOE continued coverage of the program by publishing the *Clean Coal Technology Demonstration Program: Program Update 1999,* and the mid-year update of project fact sheets, *Clean Coal Technology Demonstration Program: Project Fact Sheets 2000.*

In fiscal year 2000, the cooperative agreements for two demonstration projects expired—NOXSO Corporation's Commercial Demonstration of the NOXSO SO_2/NO_x Removal Flue Gas Cleanup System and Custom Coals International's Self-Scrubbing Coal™: An Integrated Approach—and are not discussed herein.

These accomplishments and more are described in further detail in this *Clean Coal Technology Demonstration Program: Program Update 2000.* In sum, the CCT Program is continuing to yield advances in coal technologies and thus ensures that the nation's most abundant fossil energy resource will serve the energy needs of the United States while satisfying national environmental objectives.

Demonstration of Innovative Applications of Technology for the CT-121 FGD Process Project (Southern Company Services, Inc.)—1994 Powerplant Award presented by *Power* magazine.

Role of the CCT Program

CCT Program Evolution. Coal accounts for over 94 percent of the proven fossil energy reserves in the United States and supplies the bulk of the low-cost, reliable electricity vital to the nation's economy and global competitiveness. In 1999, over half of the nation's electricity was produced with coal, and projections by the U.S. Energy Information Agency (EIA) predict that coal will continue to dominate electric power production well into the first quarter of the 21st century. However, there is a need to use U.S. coal resources in an environmentally responsible manner.

The CCT Program was established to demonstrate the commercial feasibility of CCTs to respond to a growing demand for a new generation of advanced coal-based technologies characterized by enhanced operational, economic, and environmental performance. The first solicitation (CCT-I) for clean coal projects resulted in a broad range of projects being selected in four major product markets—environmental control devices, advanced electric power generation, coal processing for clean fuels, and industrial applications.

The second solicitation (CCT-II) became the centerpiece for satisfying the recommendations contained in the Joint Report of the Special Envoys on Acid Rain (1986). The goal was to demonstrate technologies that could achieve significant reductions in the emissions of precursors of acid rain, namely SO_2 and NO_x. The third solicitation (CCT-III) furthered the goal of CCT-II and added technologies that could produce clean fuel from run-of-mine coal.

The fourth and fifth solicitations (CCT-IV and CCT-V, respectively) recognized emerging energy and environmental issues, such as global climate change and

capping SO_2 emissions, and thus focused on technologies that were capable of addressing these issues. CCT-IV called for energy efficient, economically competitive technologies capable of retrofitting, repowering, or replacing existing facilities, while at the same time significantly reducing SO_2 and NO_x emissions. CCT-V focused on technologies applicable to new or existing facilities that could significantly improve efficiency and environmental performance.

Environmental Impetus. Even before enactment of the Clean Air Act Amendments of 1990 (CAAA), the CCT Program was cognizant of the changes in electric power generation that would likely be caused by the statute. Several projects in the CCT Program were implemented at units designated as Phase I units in Title IV of the CAAA, which were required to meet SO_2 reductions by January 1, 1995. The CCT Program projects at Phase I units successfully reduced SO_2 emissions using advanced flue gas desulfurization (AFGD) and repowering with integrated gasification combined-cycle. With the January 1, 2000, Phase II Title IV CAAA provisions in effect, the CCT Program's portfolio of technologies helped industry meet the more stringent SO_2 emission limits. While SO_2 credits are being used to meet short-term goals, EIA predicts 11 GWe of capacity will be retrofitted with scrubbers to meet Phase II goals. Furthermore, these SO_2 reduction technologies may be important in meeting new requirements for $PM_{2.5}$ (particulate matter 2.5 microns and smaller in diameter) because some sulfur species are in this size range.

In addition to SO_2 reductions, Title IV also called for reductions in NO_x emissions. Phase I of the NO_x provisions of Title IV requires reductions from the so-called Group 1 boilers—tangentially fired and dry-bottom wall-fired boilers. The U.S. Environmental Protection Agency (EPA) used data developed during the CCT Program in establishing the NO_x emission standards. Under Phase II, EPA established NO_x emission limitations for Group 2 boilers and reduced the emission limits for Group 1 boilers. Group 2 boilers include cell-burner, cyclone, wet-bottom wall-fired, and vertically fired boilers. The CCT Program has demonstrated NO_x emission control techniques that are applicable to all of these boiler types. Furthermore, these technologies are not only applicable to Phase I and II NO_x emission reductions, but can be used in ozone nonattainment areas to make deeper cuts in NO_x emissions, which are a precursor to ozone.

Although the deadline has been stayed pending appeal, the EPA has issued a "SIP Call" to 22 states and the District of Columbia to take action to reduce regional transport of pollutants that contribute to ozone nonattainment in the Northeast. The SIP Call requires the 23 affected jurisdictions to revise their state implementation plans (SIPs) to reduce NO_x emissions 85 percent below 1990 rates or achieve a 0.15 $lb/10^6$ Btu emission rate by May 2003. In addition, EPA has tightened the New Source Performance Standard (NSPS) for electric and industrial boilers built or modified after July 9, 1997. The CCT Program has demonstrated several advanced electric power generation technologies that can be used to meet the new requirements or exceed the requirements to produce NO_x credits that could be sold to unit operators unable to meet the requirements. Furthermore, an environmental controls database has been developed that provides a foundation for developing technologies to meet the increasingly stringent standards for existing units.

Air toxics is another important area of environmental concern addressed by the CCT Program. Under Title I of the CAAA, EPA is responsible for determining the hazards to public health posed by 189 identified hazardous air pollutants (HAPs). The CCT Program made a significant contribution to a better understanding of potential HAPs from power plant emissions by monitoring HAPs from CCT Program project sites.

Advanced Flue Gas Desulfurization Demonstration Project (Pure Air on the Lake, L.P.)—1993 Powerplant Award presented by *Power* magazine.

The results of these and other studies have significantly mitigated concerns about HAP emissions from coal-fired power plants and focused attention on mercury emissions. In December 2000, EPA decided to develop regulations for mercury emissions over the next three years.

The CCT Program is also cognizant of concerns about global climate change. Clean coal technologies (such as IGCC) being demonstrated in the CCT Program offer utilities an option to reduce greenhouse gases (GHG) by as much as 25 percent with first-generation systems through enhanced efficiency. Commercialization of atmospheric fluidized-bed combustion (AFBC) and pressurized fluidized-bed combustion (PFBC) will also serve to reduce GHGs.

Market Considerations. As the electric generation market moves from a regulated industry to a free market, the CCT Program has kept pace with the changes. Whether the changes are brought about by the federal government through existing or new legislation or by state governments, the CCT Program is demonstrating the first generation of many technologies that will be needed in a competitive power

generation market. These new technologies will be far more efficient than existing plants and environmentally benign.

Ensuring Sustainable Economic Growth. It is in the nation's interest to maintain a diverse energy mix to sustain domestic economic growth. The CCT Program is contributing to this interest by developing and deploying a technology portfolio that enhances the efficient use of the United States' abundant coal resource while simultaneously achieving important environmental goals. The advancements in coal use technology resulting from the CCT Program will reduce dependence on foreign energy resources and create an international market for these new technologies. The worldwide market for power generation technologies could be as high as $80 billion between 1995 and 2020.

Coal Technology for the Future. The investment in the CCT Program is forming a solid foundation upon which to build a responsible future for fossil energy while addressing growing global and regional environmental concerns and providing low-cost energy. Two programs are of particular relevance to advancing the clean coal technologies demonstrated in the CCT Program. First is the Power Plant Improvement Initiative and second is Vision 21.

For the near term, the Office of Coal and Power Systems (OCPS) has embarked upon the Power Plant Improvement Initiative. The rapid growth in power demand, especially peak demand, coupled with the ongoing restructuring of the electric power industry, has resulted in a real and growing concern over the reliability of the nation's electricity grid. This concern prompted Congress to add $95 million to the Office of Fossil Energy budget for fiscal year 2001. The Power Plant Improvement Initiative approved by Congress will have a near-term focus on improving the efficiency and environmental performance of coal-fired power generation. New technologies will be demonstrated that can boost the efficiency of a power plant—increasing the amount of electricity it can generate, reducing air emissions, or perhaps a combination of both. The initial program will apply to existing and new coal-based, central power plants. Later, the program could include a wider span of more flexible generation technologies such as fuel cells and turbines that can operate on natural gas as well as coal.

For the long-term, OC&PS will build upon the solid foundation established by the CCT Program toward meeting Vision 21 goals. Vision 21 is a long-term strategic concept that integrates OC&PS program goals to develop the full potential of the nation's abundant fossil fuel resources while addressing regional and global environmental concerns. Vision 21 plants would comprise a portfolio of fuel-flexible systems and modules capable of producing a varied slate of high-value commodities, such as clean fuels, chemicals, and electricity, tailored to meet market demands in the 2010-2015 time frame. The OC&PS program areas, which include Central Power Systems, Distributed Generation, Fuels, CO_2 Sequestration, and Advanced Research, were developed to align with and directly support the goals and objectives of Vision 21 and the Comprehensive National Energy Strategy. The OC&PS program addresses key domestic and global environmental concerns, while being responsive to DOE strategies to enhance scientific understanding and promote secure, efficient, and comprehensive energy systems.

Program Implementation

Implementation Principles. There are 10 guiding principles that have been instrumental in the success of the CCT Program. These principles are:

- Strong and stable financial commitment for the life of the project, including full funding of the government's share of the costs;
- Multiple solicitations spread over a number of years, enabling the CCT Program to address a broad range of national needs with a portfolio of evolving technologies;
- Demonstrations conducted at commercial scale in actual user environments, allowing clear assessment of the technology's commercial potential;
- A technical agenda established by industry, not the government, enhancing commercialization potential;
- Clearly defined roles of government and industry, reflecting the degree of cost-sharing required;
- A requirement for at least 50 percent cost-sharing throughout all project phases, enhancing participant's commitment;
- An allowance for cost growth, but with a ceiling and cost-sharing, recognizing demonstration risk and providing an important check-and-balance to the program;
- Industry retention of real and intellectual property rights, enhancing commercialization potential;
- A requirement for industry to commit to commercialize the technology, reflecting commercialization goals; and

- A requirement for repayment up to the government's cost-share upon successful commercialization of the technology being demonstrated.

Implementation Process. Public and private sector involvement is integral to the CCT Program process and has been crucial to the program's success. Environmental concerns are publicly addressed through the process instituted under the National Environmental Policy Act (NEPA). Through programmatic environmental assessments (PEAs) and environmental impact statements (PEISs), project specific environmental assessments (EAs) and environmental impact statements (EISs), and other NEPA documents, the public is able to comment and have its comments addressed before the projects proceed to implementation. In addition, environmental monitoring programs are required for all projects to address non-regulated pollutant emissions.

As to the solicitation process, Congress set the goals for each solicitation. The Department of Energy translated the congressional guidance into performance-based criteria and developed approaches to address "lessons learned" from previous solicitations. The criteria and solicitation procedures were offered for public comment and presented at pre-proposal conferences. The solicitations were objectively evaluated against the pre-established criteria.

Projects are managed by the participants, not the government. However, to protect the public interest, safeguards are implemented to track and monitor project progress and direction. The Department of Energy interacts with the project at key negotiated decision points (budget periods) to approve or disapprove continuance of the project. Also, any changes to cost or other major project changes require DOE approval. In addition to formal project reporting requirements, an outreach program was instituted to make project information available to customers and stakeholders. This *Program Update 2000* is only one of the many public reports made available through the outreach program.

Commitment to Commercial Realization. The CCT Program has focused on achieving commercial realization since the program's inception. All five solicitations required the potential participants to address the commercial plans and approaches to be used by the participants to achieve full commercialization of the proposed technology. The cooperative agreements contain balanced provisions that provide protection for intellectual property but require the participants to make the technology available under license on a nondiscriminatory basis.

Solicitation Results. Each solicitation was issued as a Program Opportunity Notice (PON)—a solicitation mechanism for cooperative agreements where the program goals and objectives are defined, but the technology is not defined. The procurements followed specific statutory requirements that eventually led to a cooperative agreement between DOE and the participant. The result was a broad spectrum of technologies involving customers and stakeholders from all market segments. In sum, 211 proposals were submitted and 60 of those were selected. As of September 2000, a total of 38 projects have been completed or are currently active. These 38 projects are spread across the nation in 18 states.

Future Implementation Direction. The future direction of the CCT Program focuses on completing the existing projects as promptly as possible and assuring the collection, analyses, and reporting of the operational, economic, and environmental performance results that are needed to effect commercialization. In FY2001, four projects are scheduled to complete operations.

The body of knowledge obtained as a result of the CCT Program is being used in decision making relative to regulatory compliance, forging plans for meeting future energy and environmental demands, and developing the next generation of technologies responsive to ever increasing demands on environmental performance at competitive costs.

Funding and Costs

Program Funding. Congress has appropriated a federal budget of $1.8 billion for the CCT Program. For the 38 completed and active projects, the participants have contributed almost $3.5 billion dollars for a combined commitment of more than $5.2 billion. By law, DOE's contribution cannot exceed 50 percent of the total cost of any project. However, industry has stepped forward and cost shared an unprecedented 66 percent of the project funding.

Congress has provided CCT Program funding for all five solicitations through appropriation acts and adjustments. Additional activities funded by the CCT Program are the Small Business Innovation Research Program and the Small Business Technology Transfer Program. Funding is also provided for administration and management of the CCT Program. Use of appropriated funds is controlled and monitored using a variety of financial management techniques. The full government cost-share specified in the cooperative agreement is considered committed to each project; however, DOE obligates funds for the project in increments by budget period. This procedure reduces the government's financial exposure and assures that DOE fully participates in the decision to proceed with each major phase of project implementation.

Cost Sharing. As stated above, DOE's contribution cannot exceed 50 percent of the total cost of any project. Participant cost-sharing is required for all phases of the project. The federal government may share in project cost growth (which is likely to happen for any demonstration project) up to 25 percent of the original project cost. The participant's contributions must occur as expenses are incurred and cannot be delayed based on forecasted revenues, proceeds, or royalties. Also, prior investments in facilities by participants cannot count toward the participant's share.

Recovery of Government Outlays (Recoupment). The policy objective of DOE is to recover an amount of the federal government's financial contribution to each project when a technology is successfully commercialized. A recoupment agreement accompanies each demonstration agreement and stipulates the repayment provisions.

CCT Program Accomplishments

Marketplace Commitment. The success of the CCT Program ultimately will be measured by the contribution the technologies make to the resolution of energy, economic, and environmental issues. These contributions can only be achieved if the public and private sectors understand that clean coal technologies can increase the efficiency of energy use and enhance environmental performance at costs that are competitive with alternative energy options. The demonstrations, in conjunction with an aggressive outreach effort, are designed to impart that understanding. Also, the CCT Program is organized from a market perspective with projects placed in four major product lines—environmental control devices, advanced electric power generation, coal processing for clean fuels, and industrial applications. A summary of the number of projects having completed operations by category is shown in Exhibit ES-1.

The first major product line, environmental control devices, is subdivided into three groups—SO_2 control technologies, NO_x control technologies, and combined SO_2/NO_x control technologies. Both wet and dry lime- and limestone-based systems were demonstrated to achieve a range of SO_2 capture efficiencies from 50 to 99 percent. All five of the SO_2 control technology demonstrations have successfully completed operations.

For NO_x control technologies, two basic approaches were used: (1) combustion modification techniques including low-NO_x burners, overfire air, advanced controls, and reburning systems; and (2) post-combustion techniques using selective catalytic reduction (SCR) and selective non-catalytic reduction (SNCR) systems. These NO_x control techniques were applied in a variety of combinations on a diverse group of boilers, which are representative of 99 percent of the pre-NSPS boilers, *i.e.*, those boilers built before instituting NSPS under the Clean Air Act of 1970. The result of the NO_x control technology demonstrations is a portfolio of technologies that can be applied to the full range of boiler types and used to address today's pressing environmental concerns, *e.g.*, ozone. Six of the seven NO_x control technology demonstrations have successfully completed operations. For the seventh project, several final reports were issued on key facets of the project, but the project was extended for additional demonstration activities.

All six of the combined SO_2/NO_x control technology demonstrations have successfully completed operations. The demonstrations tested a multiplicity of complementary and synergistic control methods to achieve cost-effective SO_2 and NO_x emission reductions.

A summary of the results of the completed and extended environmental control device projects can be found in exhibit ES-2. The commercial successes of the environmental control devices can be seen in Exhibit ES-3.

Exhibit ES-1
Completed Projects by Application Category

Application Category	Number of Projects: Completed Operations	Number of Projects: Total
Environmental Control Devices		
SO_2 Control Technology	5	5
NO_x Control Technology	6	7
Combined SO_2/NO_x Control Technology	6	6
Advanced Electric Power Generation		
Fluidized-Bed Combustion	2	5
Integrated Gasification Combined-Cycle	1	4
Advanced Combustion/Heat Engines	1	2
Coal Processing for Clean Fuels	3	4
Industrial Applications	2	5
Total	**26**	**38**

Exhibit ES-2
Summary of Results of Completed Environmental Control Technology Projects

Project and Participant	Key Results	Capital Cost
SO_2 Control Technology		
10-MWe Demonstration of Gas Suspension Absorption (AirPol, Inc.)	Gas suspension absorption (GSA)/electrostatic precipitator (ESP)—SO_2 removal efficiency of 90% at Ca/S molar ratio of 1.4, 18 ºF approach to saturation, and 0.12% chloride (3.0% sulfur bituminous coal) GSA/pulse jet baghouse—SO_2 removal efficiency 3–5% greater than GSA/ESP (3.0% sulfur bituminous coal)	$149/kW for GSA (2.6% sulfur coal) vs. $216/kW for conventional wet limestone forced oxidation (1990$)
Confined Zone Dispersion Flue Gas Desulfurization Demonstration (Bechtel Corporation)	SO_2 reduction of 50% (1.2–2.5% sulfur bituminous coal)	Less than $30/kW at 500 MWe (4% sulfur coal) (1994$)
LIFAC Sorbent Injection Desulfurization Demonstration Project (LIFAC–North America)	SO_2 removal efficiency of 70% at 2.0 Ca/S molar ratio (2.0–2.8% sulfur bituminous coal)	$66/kW for two reactors (300 MWe); $76/kW for one reactor (150 MWe); $99/kW for one reactor (65 MWe) (1994$)
Advanced Flue Gas Desulfurization Demonstration Project (Pure Air on the Lake, L.P.)	SO_2 removal efficiency of 95% or more at availabilities of 99.5% when operating on 2.0–4.5% sulfur bituminous coal Maximum SO_2 removal efficiency of 98% Over 3-year demonstration, 237,000 tons of SO_2 removed while producing 210,000 tons of gypsum Gypsum purity—97.2% Power consumption—5,275 kW (61% of expected) Water consumption—1,560 gal/min (52% of expected)	$210/kW at 100 MWe; $121/kW at 300 MWe; $94/kW at 500 MWe (3.0% sulfur coal) (1995$)
Demonstration of Innovative Applications of Technology for the CT-121 FGD Process (Southern Company Services, Inc.)	SO_2 removal efficiency of over 95% at SO_2 inlet concentrations of 1,000–3,500 ppm using 3% sulfur coal Particulate removal efficiency of 97.7–99.3% at inlet mass loadings of 0.303–1.392 lb/10^6 Btu Agricultural-grade gypsum as a by-product Fiberglass-reinforced-plastic construction—chemically and structurally durable; eliminated the need for a flue gas prescrubber and reheat	$313/kW or $408/ton SO_2 for 100 MWe $131/kW or $171/ton SO_2 for 300 MWe $104/kW or $136/ton SO_2 for 500 MWe (Costs based on limestone at $20/ton delivered)

Exhibit ES-2 (continued)
Summary of Results of Completed Environmental Control Technology Projects

Project and Participant	Key Results	Capital Cost
NO_x Control Technology		
Demonstration of Advanced Combustion Techniques for a Wall-Fired Boiler (Southern Company Services, Inc.)	Using LNB alone, NO_x emissions were 0.65 lb/10^6 Btu at full load, representing a 48% reduction from baseline conditions (1.24 lb/10^6 Btu)	Capital cost for a 500-MWe wall-fired unit is $18.80/kW for LNB/AOFA, $8.80/kW for AOFA alone, $10.00/kW for LNB alone, and $0.50/kW for GNOCIS
	Using AOFA only, NO_x reductions of 24% below baseline conditions were achieved under normal long-term operation, depending upon load	Estimated cost of NO_x removal is $86/ton
	Using LNB/AOFA, full load NO_x emissions were approximately 0.40 lb/10^6 Btu, which represents a 68% reduction from baseline conditions	
Demonstration of Coal Reburning for Cyclone Boiler NO_x Control (The Babcock & Wilcox Company)	NO_x reductions of 52% using bituminous coal and 55% using subbituminous coal at full load (110 MWe); 36% and 53%, respectively, at 60 MWe	$66/kW at 110 MWe; $43/kW at 605 MWe (1990$)
Full-Scale Demonstration of Low-NO_x Cell Burner Retrofit (The Babcock & Wilcox Company)	NO_x reductions of 58% using bituminous coal at full load (605 MWe); 48% at 350 MWe	$9/kW at 600 MWe (1994$)
Evaluation of Gas Reburning and Low-NO_x Burners on a Wall-Fired Boiler (Energy and Environmental Research Corporation)	LNB alone (second generation)—37% NO_x reduction; GR-LNB (second generation)—64% NO_x reduction (13% gas heat input)	GR-LNB $26/kW at 300MWe; GR alone $12/kW, plus gas pipeline cost (1996$)
Micronized Coal Reburning Demonstration for NO_x Control (New York State Electric & Gas Corporation)	Using a 14% reburn fuel heat input on the Milliken Station tangentially fired (T-fired) boiler resulted in a NO_x emission rate of 0.25 lb/10^6 Btu, which represents a 28% NO_x reduction	$14/kW at 300 MWe (1999$)
	Using a 17% reburn fuel heat input on the Kodak Park cyclone boiler resulted in a NO_x emission rate of 0.60 lb/10^6 Btu, which represents a 59% NO_x reduction	
Demonstration of Selective Catalytic Reduction Technology for the Control of NO_x Emissions from High-Sulfur, Coal-Fired Boilers (Southern Company Services, Inc.)	NO_x reductions of over 80% at ammonia slip well under 5 ppm	Levelized cost at 80% NO_x reduction—2.79 mills/kWh or $2,036/ton of NO_x removed (1996$)
180-MWe Demonstration of Advanced Tangentially Fired Combustion Techniques for Reduction of NO_x Emissions from Coal-Fired Boilers (Southern Company Services, Inc.)	NO_x reductions of 37% for LNCFS™ I and II, and 45% for LNCFS™ III, which includes both separated overfire air and close-coupled overfire air	LNCFS I—$5–15/kW (1993$) LNCFS II/III—$15–25/kW (1993$)

Exhibit ES-2 (continued)
Summary of Results of Completed Environmental Control Technology Projects

Project and Participant	Key Results	Capital Cost
Combined SO_2/NO_x Control Technology		
SNOX™ Flue Gas Cleaning Demonstration Project (ABB Environmental Systems)	NO_x reduction with SCR over 94% at inlet concentrations of 500–700 ppm SO_2 removal efficiency over 95% at inlet concentrations of 2,000 ppm Produced salable sulfuric acid by-product in lieu of waste	$305/kW at 500 MWe (3.2% sulfur coal) (1995$)
LIMB Demonstration Project Extension and Coolside Demonstration (McDermott Technology, Inc.)	SO_2 removal efficiency (3.8% sulfur coal, Ca/S molar ratio of 2.0): – LIMB—53–61% for ligno lime, 51–58% for calcitic lime – Coolside—70% for hydrated lime NO_x reduction of 40–50%	LIMB—$31–102/kW (100–500 MWe) (1992$) Coolside—$69–160/kW (100–500 MWe) (1992$)
SO_x-NO_x-Rox Box™ Flue Gas Cleanup Demonstration Project (The Babcock & Wilcox Company)	SO_2 reductions of 80–90% using 3–4% sulfur bituminous coal, depending on sorbent and conditions NO_x reduction of 90% with 0.9 NH_3/NO_x ratio	$233/kW at 250 MWe (3.5% sulfur coal and inlet NO_x level of 1.2 lb/10^6 Btu) (1994$)
Enhancing the Use of Coals by Gas Reburning and Sorbent Injection (Energy and Environmental Research Corporation)	Hennepin—Average NO_x reduction of 67% with 18% gas heat input; SO_2 removal efficiency of 53% at 1.75 Ca/S molar ratio Lakeside—Average NO_x reduction of 66% and SO_2 reductions of 58% during extended continuous combined (GR-SI) runs at 29 MWe, about 22% gas heat input, and 1.8 Ca/S molar ratio	$15/kW for gas reburning, plus gas pipeline cost (1996$) $50/kW for sorbent injection
Milliken Clean Coal Technology Demonstration Project (New York State Electric & Gas Corporation)	The maximum SO_2 removal demonstrated was 98% with all seven recycle pumps operating and using formic acid. The maximum SO_2 removal without formic acid was 95% Testing of the LNCFS™ III indicated NO_x emissions of 0.39 lb/10^6 Btu (compared to 0.64 lb/10^6 Btu for the original burners), a 36% reduction	$300/kW at 300 MWe (1998$) for total capital requirements $217/kW at 300 MWe for total plant costs and $83/kW for other related costs $4,620,000/yr for O&M costs

Exhibit ES-2 (continued)
Summary of Results of Completed Environmental Control Technology Projects

Project and Participant	Key Results	Capital Cost
Combined SO_2/NO_x Control Technology (continued)		
Integrated Dry NO_x/SO_2 Emissions Control System (Public Service Company of Colorado)	NO_x reduction of 62–69% with low-NO_x burners and maximum overfire air (50–110 MWe) NO_x reduction of 63% with low-NO_x burners and minimum overfire air; steady state conditions NO_x reduction decreased by 10–25% under load following SNCR obtained NO_x reduction of 30–50%, thereby increasing total NO_x control system reduction to more than 80% SO_2 removal efficiency of 70% with sodium bicarbonate at normalized stoichiometric ratio of 1.0	$125/kW at 300 MWe for total capital requirements $281/kW at 50 MWe for total capital requirements

Exhibit ES-3
Commercial Successes—Environmental Control Technologies

Project	Commercial Use
10-MWe Demonstration of Gas Suspension Absorption (AirPol, Inc.)	**Sold domestically and internationally.** GSA market entry was significantly enhanced with the sale of a 50-MWe unit, worth $12.5 million, to the city of Hamilton, Ohio, subsidized by the Ohio Coal Development Office. A sale worth $1.3 million has been made to the U.S. Army for hazardous waste disposal. A GSA system has been sold to a Swedish iron ore sinter plant. Two GSA systems valued at $1.8 million have been sold to Taiwan Sugar Corporation for their oil-fired cogeneration plant. Furthermore, Taiwan contracted for technical assistance and proprietary equipment valued at $1.0 million. AirPol sold a GSA system valued at $1.5 million to a petroleum coke calciner in India. Negotiations are under way for a GSA system for a waste incinerator in Holland.
Confined Zone Dispersion Flue Gas Desulfurization Demonstration (Bechtel Corp.)	**No sales reported.** CZD/FGD can be used to retrofit existing plants or for new installations at a cost of about one-fourth the cost of a commercial wet scrubber.
LIFAC Sorbent Injection Desulfurization Demonstration Project (LIFAC–North America)	**Sold domestically and internationally.** There are 10 LIFAC units in operation in Canada, China, Finland, Japan, Russia, and the United States, including 5 projects started before the CCT Program. The LIFAC system at Richmond Power & Light is the first to be applied to a power plant using high-sulfur (2.0-2.9%) coal. The LIFAC system has been retained for commercial use by Richmond Power & Light at Whitewater Valley Station, Unit No. 2.
Advanced Flue Gas Desulfurization Demonstration Project (Pure Air on the Lake, L.P.)	**No sales reported.** The AFGD continues in commercial service at Northern Indiana Public Service Company's Bailly Generating Station. Gypsum produced by the PowerChip® process is being sold commercially.
Demonstration of Innovative Applications of Technology for the CT-121 FGD Process (Southern Company Services, Inc.)	**Sold internationally.** Plant Yates continues to operate with the CT-121 scrubber as an integral part of the site's CAAA compliance strategy. Since the CCT Program demonstration, over 8,200 MWe equivalent of CT 121 FGD capacity are operating at 17 plants in 8 countries. Another 5 projects are either in design or construction.
Micronized Coal Reburning Demonstration for NO_x Control (New York State Electric & Gas Corp.)	**No sales reported.** Technology retained for commercial use at Kodak Power Plant.
Demonstration of Coal Reburning for Cyclone Boiler NO_x Control (The Babcock & Wilcox Company)	**No sales reported.** Technology retained for commercial use at Wisconsin Power and Light Company's Nelson Dewy Station
Full-Scale Demonstration of Low-NO_x Cell Burner Retrofit (The Babcock & Wilcox Company)	**Sold domestically.** Dayton Power & Light has retained the LNCB® for use in commercial service. Seven commercial contracts have been awarded for 172 burners, valued at $27 million. The LNCB® technology has already been installed on more than 4,900 MWe of capacity.
Evaluation of Gas Reburning and Low-NO_x Burners on a Wall-Fired Boiler (Energy and Environmental Research Corp.)	**Sold domestically and internationally.** Public Service Company of Colorado, the host utility, decided to retain the low-NO_x burners and the gas-reburning system for immediate use; however, a restoration was required to remove the flue gas recirculation system. Energy and Environmental Research Corporation has been awarded two contracts to provide gas reburning systems for cyclone coal-fired boilers: TVA's Allen Unit 1 (a 330-MWe unit) as well as Baltimore Gas & Electric's C. P. Crane Units 1 and 2 (similar 200-MWe units). The technology is also installed at Ladyzkin State Power Station in Ladyzkin, Ukraine.

Exhibit ES-3 (continued)
Commercial Successes—Environmental Control Technologies

Project	Commercial Use
Demonstration of Selective Catalytic Reduction Technology for the Control of NO_x Emissions from High-Sulfur, Coal-Fired Boilers (Southern Company Services, Inc.)	**Sold domestically and internationally.** Since the project was initiated, revenues from sales achieved $2.7 billion through 2000, with projected revenues for 2001 and 2002 expected to be $1.4 billion and $1.3 billion, respectively.
180-MWe Demonstration of Advanced Tangentially Fired Combustion Techniques for the Reduction of NO_x Emissions from Coal-Fired Boilers (Southern Company Services, Inc.)	**Sold domestically and internationally.** LNCFS™ has been retained at the host site for commercial use. ABB Combustion Engineering has sold about 56 GWe of LNCFS™ burners. Of this amount, about 23 GWe are equipped with overfire air and 33 GWe are without overfire air. Total sales are estimated at $1 billion.
Demonstration of Advanced Combustion Techniques for a Wall-Fired Boiler (Southern Company Services, Inc.)	**Sold domestically and internationally.** The host has retained the technologies for commercial use. Foster Wheeler has equipped 86 boilers (51 domestic and 35 international) with low-NO_x burner technology—a total of over 1,800 burners representing over 30,000 MWe of capacity valued at $55 million. Twenty-six commercial installations of GNOCIS, the associated AI control system, are underway or planned. This represents over 12,000 MWe of capacity. In a strict sense, this project has not been completed; it has been extended to apply GNOCIS to other pieces of plant equipment, which may increase its commercial potential.
SNOX™ Flue Gas Cleaning Demonstration Project (ABB Environmental Systems)	**International use.** The host utility, Ohio Edison, is retaining the SNOX™ technology as a permanent part of the pollution control system at Niles Station to help meet its overall SO_2 and NO_x reduction goals. Commercial SNOX™ plants are also operating in Denmark and Sicily. In Denmark, a 305-MWe plant has operated since August 1991. The boiler at this plant burns coals from various suppliers around the world, including the United States; the coals contain 0.5–3.0% sulfur. The plant in Sicily, in operation since March 1991, has a capacity of about 30 MWe and fires petroleum coke.
LIMB Demonstration Project Extension and Coolside Demonstration (The Babcock & Wilcox Company)	**Sold domestically and internationally.** LIMB has been sold to an independent power plant in Canada. Babcock & Wilcox has sales of 2,585 burners for 35,310 MWe of capacity for the DRB-XCL® low-NO_x burners. The low-NO_x burners have an estimated value of $320 million.
SO_x-NO_x-Rox Box™ Flue Gas Cleanup Demonstration Project (The Babcock & Wilcox Company)	**No sales reported.** Commercialization of the technology is expected to develop with an initial larger scale application equivalent to 50–100 MWe. The focus of marketing efforts is being tailored to match the specific needs of potential industrial, utility, and independent power producers for both retrofit and new plant construction. SNRB™ is a flexible technology that can be tailored to maximize control of SO_2, NO_x, particulate, or combined emissions to meet current performance requirements while providing flexibility to address future needs.
Enhancing the Use of Coals by Gas Reburning and Sorbent Injection (Energy and Environmental Research Corp.)	**No sales reported.** Illinois Power has retained the gas-reburning system and City Water, Light & Power has retained the full technology for commercial use. (See Evaluation of Gas Reburning and Low-NO_x Burner on a Wall-Fired Boiler project for a complete understanding of commercial success of the technology.)

Exhibit ES-3 (continued)
Commercial Successes—Environmental Control Technologies

Project	Commercial Use
Milliken Clean Coal Technology Demonstration Project (New York State Electric & Gas Corp.)	**Sold domestically.** Eight modules of DHR Technologies' Plant Emissions Optimization Advisor, with an estimated value of $210,000, have been sold. A U.S. company, SHN, has been established to market the S-H-U scrubber. SHN is pursuing an advanced flue gas desulfurization bid for a Pennsylvania site. ABB Combustion Engineering has modified 116 units representing over 25,000 MWe with LNCFS™ or its derivative TFS 2000™.
Integrated Dry NO_x/SO_2 Emissions Control System (Public Service Company of Colorado)	**Sold domestically.** The technology was retained by Public Service Company of Colorado for commercial service at its Arapahoe Station. The Babcock & Wilcox DRB-XCL® burner that was demonstrated has realized sales of 2,428 burners, representing 31,467 MWe. The burners are valued at $240 million.

The second major product line, advanced electric power generation, is subdivided into three groups—(1) fluidized-bed combustion, (2) integrated gasification combined-cycle, and (3) advanced combustion/heat engines. These technologies can be used for repowering existing plants and for new plants.

For fluidized-bed combustion, two approaches were used: atmospheric fluidized-bed combustion and pressurized fluidized-bed combustion. The two AFBC projects use a circulating-bed, as opposed to a bubbling-bed, operating at atmospheric pressure to generate steam for electricity production. One project is complete and the other project is ongoing. There are three PFBC projects in the CCT Program. The completed PFBC project used a bubbling-bed operating at 16 atmospheres to generate steam and drive a gas turbine in a combined-cycle mode. Two interrelated PFBC projects, which are now on hold pending further analysis for generation needs by the participant, will use a circulating-bed operating at 13 atmospheres, in a combined-cycle mode.

The PC-based software tool CQE™ can be used to determine the complete costs of various fuel options by integrating the effects of fuel purchase decisions on power plant performance, emissions, and power generation costs.

During fiscal year 2000, one integrated gasification combined-cycle (IGCC) project successfully completed operations, two IGCC projects were in operation, and a fourth IGCC project was in the design stage. The IGCC projects represent a diversity of gasifier types, cleanup systems, and applications.

Two projects are demonstrating advanced combustion/heat engine technology. One uses an entrained (slagging) combustor, and the other uses a heavy duty diesel fired on a coal-water fuel. One project completed operations in fiscal year 2000 and the other project is ongoing.

A summary of the results of the completed advanced electric power generation projects can be found in Exhibit ES-4. The commercial successes of these projects can be seen in Exhibit ES-5.

For the third major product line, coal processing for clean fuels, there are four projects. Two projects are using chemical and physical processes to transform raw coal into high-energy-density environmentally compliant fuels. Another project is converting coal to methanol from coal-derived synthesis gas. A fourth project in this product line is a software program used to assess the environmental and operational performance of and determine the least-cost option for available coals. Two of the four coal processing for clean fuels projects are complete.

A summary of the results of the completed coal processing for clean fuels projects can be found in Exhibit ES-6. The commercial successes of the coal processing for clean fuels projects can be seen in Exhibit ES-7.

The fourth and final major product line is industrial applications. This product line is addressing the environmental issues and barriers associated with coal use in industry. There are five diverse projects in this category; three are completed and two are ongoing.

A summary of the results of the industrial application projects can be found in Exhibit ES-8. Commercial successes of these projects can be seen in Exhibit ES-9.

Market Communications—Outreach. Outreach has been a hallmark of the CCT Program since it's inception. Commercialization of new technologies requires

Wabash River Coal Gasification Repowering Project (Wabash River Coal Gasification Repowering Project Joint Venture)—1996 Powerplant Award presented by *Power* magazine.

Full-Scale Demonstration of Low-NO_x Cell Burner Retrofit Project (The Babcock & Wilcox Company)—1994 R&D 100 Award presented by *R&D* magazine.

Exhibit ES-4
Summary of Results of Completed Advanced Electric Power Generation Projects

Project and Participant	Key Results	Capital Cost
Tidd PFBC Demonstration Project (The Ohio Power Company)	SO_2 reduction of 90–95% (Ohio bituminous coal, 2–4% sulfur) at 1.1–1.5 Ca/S molar ratio NO_x emissions of 0.15–0.33 lb/10^6 Btu Particulate emissions of 0.02 lb/10^6 Btu Heat rate—10,280 Btu/kWh Combustion efficiency—99.6% Commercially viable design Gas turbine operable in PFBC environment	$1,263/kW at 360 MWe (1997$)
Nucla CFB Demonstration Project (Tri-State Generation and Transmission Association, Inc.)	SO_2 reduction of 70–95% (up to 1.8% sulfur coal), depending on Ca/S molar ratio NO_x emissions of 0.18 lb/10^6 Btu Particulate emissions of 0.0072–0.0125 lb/10^6 Btu Heat rate—11,600 Btu/kWh Combustion efficiency—96.9–98.9% Commercial viability established	Approximately $1,123/net kW (repowering cost) (1990$)
Healy Clean Coal Project (Arthur D. Little, Inc.)	SO_2 reduction in excess of 90% (Usibelli subbituminous 50% run-of-mine and 50% waste coal) at 1.4–1.8 Ca/S molar ratio NO_x emissions of 0.208–0.278 lb/10^6 Btu Particulate emissions of 0.0047 lb/10^6 Btu Greater than 99% carbon burnout at 100% maximum continuous rating	Economic data are not yet available

Exhibit ES-5
Commercial Successes—Advanced Electric Power Generation Technologies

Project	Commercial Use
Tidd PFBC Demonstration Project (The Ohio Power Company)	**Sold internationally.** Success of the project has led Babcock & Wilcox to invest in the technology and acquire domestic licensing rights. Commercial ventures abroad include the following: – Vartan Sweden is operating two P200 units to produce 135 MWe and 224 MWth – Escatron in Spain is operating one P200 unit producing 80 MWe – Wakamatsu in Japan is operating one P200 unit to produce 71 MWe – Cottbus in Germany is operating one P200 unit to produce 71 MWe and 40 MWth – Karita in Japan operates one P800 unit to produce 360 MWe – Other projects under construction are in China, South Korea, U.K., and Israel
Nucla CFB Demonstration Project (Tri-State Generation and Transmission Association, Inc.)	**Sold domestically and internationally.** Since the demonstration, Foster Wheeler Energy Corporation, the technology supplier for the demonstration effort, has achieved sales of $7.9 billion through 2000, with another $2.7 billion in sales projected for 2001 through 2003. Twenty-one percent of the sales through 2000 were domestic, while the remaining sales through 2000 were foreign.
Tampa Electric Integrated Gasification Combined-Cycle Project (Tampa Electric Company)	**Sold domestically and internationally.** First greenfield IGCC unit in commercial service. Texaco, Inc., and ASEA Brown Boveri signed an agreement forming an alliance to market IGCC technology in Europe. There are currently 10 projects using a Texaco gasifier that are either planned or under construction.
Wabash River Coal Gasification Repowering Project (Wabash River Coal Gasification Repowering Project Joint Venture)	**No sales reported.** First repowered IGCC unit in commercial service and world's largest single train IGCC in commercial service. Preferentially dispatched over other coal-fired units in PSI Energy's system because of high efficiency.
Healy Clean Coal Project (Alaska Industrial Development and Export Authority)	**No sales reported.** TRW offering licensing of combustor worldwide (China agreement in place).

Exhibit ES-6
Summary of Results of Completed Coal Processing for Clean Fuels Projects

Project and Participant	Key Results	Capital Cost
Development of the Coal Quality Expert™ (ABB Combustion Engineering, Inc. and CQ Inc.)	CQE™ features: - Fuel evaluator—performs system-, plant-, and/or unit-level fuel quality, economic, and technical assessments - Plant engineer—provides in-depth performance evaluations with a more focused scope than provided in the fuel evaluator - Environmental planner—provides access to evaluation and presentation capabilities of the Acid Rain Advisor - Coal cleaning expert—establishes the feasibility of cleaning a coal, determines cleaning processes, and predicts associated costs	CQE™ package sells for between $75,000 and $100,000
ENCOAL® Mild Gasification Project (ENCOAL Corporation)	The liquid (CDL®) and solid (PDF®) product fuels have been used economically in commercial boilers and furnaces and have reduced SO_2 and NO_x emissions significantly at utility and industrial facilities currently burning high-sulfur bituminous coal or fuel oils Almost five years of operating data have been collected for use as a basis for the evaluation and design of a commercial plant About 260,000 tons of coal had been processed into 120,000 tons of PDF® and 5,101,000 gallons of CDL®	A commercial plant designed to process 15,000 metric-ton/day would cost $475 million (2001$) to construct with annual operating and maintenance costs of $52 million per year

Exhibit ES-7
Commercial Successes—Coal Processing for Clean Fuels Technologies

Project	Commercial Use
Development of the Coal Quality Expert™ (ABB Combustion Engineering, Inc. and CQ Inc.)	**Sold domestically and internationally.** The Electric Power Research Institute (EPRI) owns the software and distributes it to EPRI members for their use. CQ Inc. and Black and Veatch have signed commercialization agreements that give both companies nonexclusive worldwide rights to sell user licenses and offer consulting services that include use of CQE®. More than 22 U.S. utilities, two United Kingdom utilities, and one French utility have received CQE® through EPRI membership. Two modules of the Acid Rain Advisor valued at $6,000 have been sold. EPRI estimated that the Acid Rain Advisor saved one U.S. utility about $26 million, more than the total cost of the demonstration project. There have been two sales of the Windows version of the software at an estimated value of $180,000.
ENCOAL® Mild Coal Gasification Project (ENCOAL Corporation)	**Domestic and international sales pending.** In order to determine the viability of potential LFC® plants, five detailed commercial feasibility studies—two Indonesian, one Russian, and two U.S. projects—have been completed. Permitting of a 15,000 metric-ton/day commercial plant in Wyoming is nearly complete.
Advanced Coal Conversion Process Demonstration (Western SynCoal LLC)	**No sales reported.** Total sales of SynCoal® product exceed 1.5 million tons. Six long-term agreements are in place to purchase the product. One domestic and five international projects have been investigated. Western SynCoal LLC has a joint marketing agreement with Ube Industries of Japan providing Ube non-exclusive marketing rights outside of the United States. Ube is pursuing several projects in Asia. Western SynCoal is also discussing a potential marketing and development agreement with a U.S. engineering firm.
Commercial-Scale Demonstration of the Liquid Phase Methanol (LPMEOH™) Process (Air Products Liquid Phase Conversion Company , L.P.)	**No sales reported.** Nominal 80,000 gallon/day methanol production being used by Eastman Chemical Company

Exhibit ES-8
Summary of Results of Completed Industrial Application Projects

Project and Participant	Key Results	Capital Cost
Advanced Cyclone Combustor with Internal Sulfur, Nitrogen, and Ash Control (Coal Tech Corporation)	SO_2 reduction of 58% with limestone injection in the combustor at 2.0 Ca/S molar ratio NO_x emissions of 160–184 ppm (75% reduction) Slag/sorbent retention of 55–90% in combustor; inert slag	Not available
Cement Kiln Flue Gas Recovery Scrubber (Passamaquoddy Tribe)	SO_2 reduction of 90–95% (2.5–3% sulfur bituminous coal); 98% maximum reduction NO_x reduction of 18.8% avg Particulate emissions of 0.005–0.007 gr/std ft^3 with loading of 0.04 gr/std ft^3	$10 million for 450,000 ton/yr wet-process plant (1990$)
Blast Furnace Granular-Coal Injection Demonstration Project (Bethlehem Steel Corporation)	The low-volatile, low-ash coal displaced up to 0.96 pounds of coke for every pound of coal No increase in sulfur emissions Sulfur levels in product remained within specified limits	$15 million for a single blast furnace producing 7,200 net tons of hot metal per day

Exhibit ES-9
Commercial Successes—Industrial Application Technologies

Project	Commercial Use
Advanced Cyclone Combustor with Internal Sulfur, Nitrogen, and Ash Control (Coal Tech Corporation)	**No sales reported.** While the combustor was not yet fully ready for sale with commercial guarantees, it was believed to have commercial potential. Subsequent work was undertaken, which has brought the technology close to commercial introduction.
Cement Kiln Flue Gas Recovery Scrubber (Passamaquoddy Tribe)	**No sales reported.** The scrubber became a permanent part of the cement plant at the end of the demonstration. A feasibility study has been completed for a Taiwanese cement plant.
Blast Furnace Granular-Coal Injection System Demonstration Project (Bethlehem Steel Corporation)	**Domestic sale.** British Steel's Blast Furnace Granular Coal Injection System was sold and installed on a facility owned by United States Steel Corporation.

acceptance by a wide range of interests—customers, manufacturers, suppliers, financiers, government, and public interest groups. The CCT Program has aggressively sought to disseminate key information to this full range of customers and stakeholders and to obtain feedback on changing needs. This dissemination of information takes the form of printed media, exhibits, and electronic media. Printed media consist of newsletters, proceedings, technical papers, fact sheets, program updates, and bibliographies. The CCT Program currently uses four traveling exhibits of varying sizes and complexity that can be updated and tailored to specific forums. A fifth exhibit is being developed to replace an older exhibit that will be retired. Electronic media are available through the World Wide Web.

Feedback is another important part of the outreach effort. From public meetings during the PON process to open houses at demonstration sites, the CCT Program stays in contact with customers and stakeholders. Executive seminars, stakeholder meetings, conferences, workshops, and trade missions are used by the CCT Program to disseminate information and obtain feedback.

Several domestic and international conferences and workshops were attended or sponsored in fiscal year 2000. The forums for conferences varied from Slovakia to Japan. Trade missions during fiscal year 2000 included South Africa and India. The Department of Energy also provided support for the Foreign Service Training Course. All of these events were used to endorse and promote the technologies demonstrated in the CCT Program.

CCT Projects

Technology Overview. The 38 CCT Program projects provide a portfolio of technologies that will enable coal to continue to provide low-cost secure energy vital to the nation's economy while satisfying energy and environmental goals well into the 21st century.

Environmental Control Devices. The environmental control technologies provide a suite of cost-effective control options for the full range of boiler types. The 17 environmental control device projects are valued at $620 million. These include seven NO_x emission control systems installed in more than 1,750 MWe of utility generating capacity, five SO_2 emission control systems installed on approximately 770 MWe, and six combined SO_2/NO_x emission control systems installed or planned for installation on more than 665 MWe of capacity.

Advanced Electric Power Generation. To respond to load growth, as well as growing environmental concerns, the CCT Program provides a range of advanced electric power generation options for both repowering and new power generation. These advanced options offer greater than 20 percent reductions in greenhouse gas emissions; SO_2, NO_x, and particulate emissions far below NSPS; and salable solid and liquid by-products in lieu of solid wastes. Over 1,800 MWe of capacity are represented by 11 projects valued at more than $2.8 billion. These projects will not only provide environmentally sound electric generation now, but also will provide the demonstrated technology base necessary to meet new capacity requirements in the 21st century.

Coal Processing for Clean Fuels. Also addressed are approaches to converting run-of-mine coals to high-energy-density, low-sulfur products. These products have application domestically for compliance with the CAAA. Internationally, both the products and processes have excellent market potential. Valued at almost $432 million, the four projects in the coal processing for clean fuels category represent a diversified portfolio of technologies.

Industrial Processes. Projects were undertaken as well to address pollution problems associated with coal use in the industrial sector. The problems addressed include dependence of the steel industry on coke and the pollutant emissions inherent in coke making; reliance of the cement industry on low-cost indigenous, and often high-sulfur, coal fuels; and the need for many industrial boiler operators to consider switching to coal fuels to reduce operating costs. The five industrial applications projects have a combined value of nearly $1.3 billion. The projects encompass substitution of coal for 40 percent of coke in iron making; integration of a direct iron-making process with the production of electricity; reduction of cement kiln emissions and solid waste generation; demonstration of an industrial-scale slagging combustor; and demonstration of a pulse combustor system.

Project Fact Sheets. The core of this *Program Update 2000* is the project fact sheets. Two types of fact sheets are provided: (1) a brief two-page overview for ongoing projects and (2) an expanded four-page summary for projects that have successfully completed operational testing. The latter contains a summary of the major results from the demonstrations, as well as sources for obtaining further information. Technology descriptions, costs, and schedules are provided for all projects. A list of the projects with the participant, solicitation, and status is shown in Exhibit ES-10. A list of the award-winning CCT Program projects is shown in Exhibit ES-11.

Exhibit ES-10
Project Fact Sheets by Application Category

Project	Participant	Solicitation/Status	Page
Environmental Control Devices			
SO_2 Control Technologies			
10-MWe Demonstration of Gas Suspension Absorption	AirPol, Inc.	CCT-III/completed 3/94	5-22
Confined Zone Dispersion Flue Gas Desulfurization Demonstration	Bechtel Corporation	CCT-III/completed 6/93	5-26
LIFAC Sorbent Injection Desulfurization Demonstration Project	LIFAC-North America	CCT-III/completed 6/94	5-30
Advanced Flue Gas Desulfurization Demonstration Project	Pure Air on the Lake, L.P.	CCT-II/completed 6/95	5-34
Demonstration of Innovative Applications of Technology for the CT-121 FGD Process	Southern Company Services, Inc.	CCT-II/completed 12/94	5-38
NO_x Control Technologies			
Demonstration of Advanced Combustion Techniques for a Wall-Fired Boiler	Southern Company Services, Inc.	CCT-II/extended	5-44
Demonstration of Coal Reburning for Cyclone Boiler NO_x Control	The Babcock & Wilcox Company	CCT-II/completed 12/92	5-48
Full-Scale Demonstration of Low-NO_x Cell Burner Retrofit	The Babcock & Wilcox Company	CCT-III/completed 4/93	5-52
Evaluation of Gas Reburning and Low-NO_x Burners on a Wall-Fired Boiler	Energy and Environmental Research Corporation	CCT-III/completed 1/95	5-56
Micronized Coal Reburning Demonstration for NO_x Control	New York State Electric & Gas Corporation	CCT-IV/completed 4/99	5-60
Demonstration of Selective Catalytic Reduction Technology for the Control of NO_x Emissions from High-Sulfur, Coal-Fired Boilers	Southern Company Services, Inc.	CCT-II/completed 7/95	5-64
180-MWe Demonstration of Advanced Tangentially Fired Combustion Techniques for the Reduction of NO_x Emissions from Coal-Fired Boilers	Southern Company Services, Inc.	CCT-II/completed 12/92	5-68
Combined SO_2/NO_x Control Technologies			
SNOX™ Flue Gas Cleaning Demonstration Project	ABB Environmental Systems	CCT-II/completed 12/94	5-74
LIMB Demonstration Project Extension and Coolside Demonstration	The Babcock & Wilcox Company	CCT-I/completed 8/91	5-78
SO_x-NO_x-Rox Box™ Flue Gas Cleanup Demonstration Project	The Babcock & Wilcox Company	CCT-II/completed 5/93	5-82
Enhancing the Use of Coals by Gas Reburning and Sorbent Injection	Energy and Environmental Research Corporation	CCT-I/completed 10/94	5-86
Milliken Clean Coal Technology Demonstration Project	New York State Electric & Gas Corporation	CCT-IV/completed 6/98	5-90
Integrated Dry NO_x/SO_2 Emissions Control System	Public Service Company of Colorado	CCT-III/completed 12/96	5-94
Advanced Electric Power Generation			
Fluidized-Bed Combustion			
McIntosh Unit 4A PCFB Demonstration Project	City of Lakeland, Lakeland Electric	CCT-III/design	5-100
McIntosh Unit 4B Topped PCFB Demonstration Project	City of Lakeland, Lakeland Electric	CCT-V/design	5-102
JEA Large-Scale CFB Combustion Demonstration Project	JEA	CCT-I/design	5-104

Shaded area indicates projects having completed operations.

Exhibit ES-10 (continued)
Project Fact Sheets by Application Category

Project	Participant	Solicitation/Status	Page
Tidd PFBC Demonstration Project	The Ohio Power Company	CCT-I/completed 3/95	5-106
Nucla CFB Demonstration Project	Tri-State Generation and Transmission Association, Inc.	CCT-I/completed 1/91	5-110
Integrated Gasification Combined-Cycle			
Kentucky Pioneer Energy IGCC Demonstration Project	Kentucky Pioneer Energy, LLC	CCT-V/design	5-116
Piñon Pine IGCC Power Project	Sierra Pacific Power Company	CCT-IV/operational	5-118
Tampa Electric Integrated Gasification Combined-Cycle Project	Tampa Electric Company	CCT-III/operational	5-120
Wabash River Coal Gasification Repowering Project	Wabash River Coal Gasification Repowering Project Joint Venture	CCT-IV/completed 12/99	5-122
Advanced Combustion/Heat Engines			
Clean Coal Diesel Demonstration Project	Arthur D. Little, Inc.	CCT-V/construction	5-128
Healy Clean Coal Project	Alaska Industrial Development and Export Authority	CCT-III/completed 12/99	5-130
Coal Processing for Clean Fuels			
Commercial-Scale Demonstration of the Liquid Phase Methanol (LPMEOH™) Process	Air Products Liquid Phase Conversion Company, L.P.	CCT-III/operational	5-136
Advanced Coal Conversion Process Demonstration	Western SynCoal LLC	CCT-I/operational	5-138
Development of the Coal Quality Expert™	ABB Combustion Engineering, Inc. and CQ Inc.	CCT-I/completed 12/95	5-140
ENCOAL® Mild Coal Gasification Project	ENCOAL Corporation	CCT-III/completed 7/97	5-144
Industrial Applications			
Clean Power from Integrated Coal/Ore Reduction (CPICOR™)	CPICOR™ Management Company LLC	CCT-V/design	5-150
Pulse Combustor Design Qualification Test	ThermoChem, Inc.	CCT-IV/construction	5-152
Blast Furnace Granular-Coal Injection System Demonstration Project	Bethlehem Steel Corporation	CCT-III/completed 11/98	5-154
Advanced Cyclone Combustor with Internal Sulfur, Nitrogen, and Ash Control	Coal Tech Corporation	CCT-I/completed 5/90	5-158
Cement Kiln Flue Gas Recovery Scrubber	Passamaquoddy Tribe	CCT-II/completed 9/93	5-162

Shaded area indicates projects having completed operations.

Exhibit ES-11
Award-Winning CCT Projects

Project and Participant	Award
Full-Scale Demonstration of Low-NO_x Cell Burner Retrofit (The Babcock & Wilcox Company)	1994 R&D 100 Award presented by *R&D* magazine to the U.S. Department of Energy for development of the low-NO_x cell burner.
Evaluation of Gas Reburning and Low-NO_x Burners on a Wall-Fired Boiler; Enhancing the Use of Coals by Gas Reburning and Sorbent Injection (Energy and Environmental Research Corporation)	1997 J. Deanne Sensenbaugh Award presented by the Air and Waste Management Association to the U.S. Department of Energy, Gas Research Institute, and U.S. Environmental Protection Agency for the development and commercialization of gas-reburning technology.
Advanced Flue Gas Desulfurization Demonstration Project (Pure Air on the Lake, L.P.)	1993 Powerplant Award presented by *Power* magazine to Northern Indiana Public Service Company's Bailly Generating Station.
	1992 Outstanding Engineering Achievement Award presented by the National Society of Professional Engineers.
Demonstration of Innovative Applications of Technology for the CT-121 FGD Process (Southern Company Services, Inc.)	1995 Design Award presented by the Society of Plastics Industries in recognition of the mist eliminator.
	1994 Powerplant Award presented by *Power* magazine to Georgia Power's Plant Yates. Co-recipient was the U.S. Department of Energy.
	1994 Outstanding Achievement Award presented by the Georgia Chapter of the Air and Waste Management Association.
	1993 Environmental Award presented by the Georgia Chamber of Commerce.
Tidd PFBC Demonstration Project (The Ohio Power Company)	1992 National Energy Resource Organization award for demonstration of energy-efficient technology.
	1991 Powerplant Award presented by *Power* magazine to American Electric Power Company's Tidd project. Co-recipient was The Babcock & Wilcox Company.
Tampa Electric Integrated Gasification Combined-Cycle Project (Tampa Electric Company)	1997 Powerplant Award presented by *Power* magazine to Tampa Electric's Polk Power Station.
	1996 Association of Builders and Contractors Award presented to Tampa Electric for quality of construction.
	1993 Ecological Society of America Corporate Award presented to Tampa Electric for its innovative siting process.
	1993 Timer Powers Conflict Resolution Award presented to Tampa Electric by the state of Florida for the innovative siting process.
	1991 Florida Audubon Society Corporate Award presented to Tampa Electric for the innovative siting process.
Wabash River Coal Gasification Repowering Project (Wabash River Coal Gasification Repowering Project Joint Venture)	1996 Powerplant Award presented by *Power* magazine to CINergy Corp./PSI Energy, Inc.
	1996 Engineering Excellence Award presented to Sargent & Lundy upon winning the 1996 American Consulting Engineers Council competition.
Development of the Coal Quality Expert™ (ABB Combustion Engineering, Inc. and CQ Inc.)	In 1996 recognized by then Secretary of Energy Hazel O'Leary and EPRI President Richard Balzhiser as the best of nine DOE/EPRI cost-shared utility R&D projects under the Sustainable Electric Partnership Program.

Benefits Legacy

The CCT Program, in conjunction with other government-sponsored coal research, development, and demonstration (RD&D) projects and partnerships, has resulted in a broad range of environmental and economic benefits. DOE efforts to advance coal technologies prior to the CCT Program, through the CCT Program, and via ongoing RD&D programs have been highly complementary and successful. Close-working relationships between government and industry have accelerated market entry of the advanced technologies emerging from these collaborative efforts, as well as the realization of the related benefits. Exhibit ES-12 summarizes some of the benefits derived from the CCT Program, associated RD&D partnerships, and the resultant technologies.

Exhibit ES-12

Benefits Legacy from CCT Program and Associated RD&D

NO_x Control Technologies

- 75% of existing U.S. coal-fired units have been or currently are being retrofitted with low-NO_x burners.
- $1.3 billion in commercial foreign and domestic sales of low-NO_x burners have been realized.
- A 50% reduction in SCR costs has resulted since 1980.
- An estimated 30% of U.S. coal-fired generating capacity will incorporate SCR technology by 2004.
- Over 60 million tons of NO_x emissions have been avoided since 1970 based on average fleet emissions.

SO_2 Control Technologies

- A 30% reduction in FGD costs has resulted since the early 1990s.
- An estimated 30% of U.S. coal-fired generating capacity will incorporate FGD technology by 2002.
- 127 million tons of SO_2 emissions have been avoided since 1970 as a result of FGD installations.

Fluidized-Bed Combustion Technologies

- Well over 100 domestic and more than 400 overseas industrial and utility FBCs are in operation.
- Since the CCT demonstrations, at least 29 units greater than 100 MWe have been sold, representing over 6,000 MWe of capacity valued at over $6 billion.
- FBCs offer inherently low NO_x emissions, high combustion and SO_2 capture efficiency, and extreme fuel flexibility—e.g., six FBCs in Pennsylvania are using coal waste as fuel, eliminating an environmental problem, saving $1 billion in fuel costs, and avoiding 1.8 million tons of NO_x emissions over their life.

Integrated Gasification Combined Cycle Technologies

- Over 5,600 MWe of IGCC, designed for a multiplicity of fuels, is in operation or in design, 1,500 MWe of which is coal-fired and in operation.
- 16,500 MWe of IGCC is expected to be operating in the United States by 2020.
- The more than 1,100 MWe of CCT demonstration unit capacity will avoid an estimated 224,000 tons of SO_2 and 312,000 tons of NO_x over the life of the units.

Life-Cycle Cost Savings to Industry and the Public for Near-Term Deployment

- Lower capital and operating costs for advanced power plants and NO_x and SO_2 pollution control systems equate to $23 billion.
- Lower compliance costs for air toxics and solid waste, through technology development, is estimated at $70 billion.
- Market value of SO_2 and NO_x reduction is estimated at $10 billion.
- Improved waste characterization and advances in waste recovery are estimated to result in a $25 billion cost benefit.